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# A Comparison of Bipolar and Monopolar Diathermy Probes in Experimental Animals

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**Abstract.** The effects of monopolar and bipolar diathermy were studied in laboratory animals. The power required to coagulate transected vessels in air was established and the effect of immersion in saline and water during electrocoagulation was investigated. Tissue heat conduction from each type of probe was measured and compared. Tissue damage was assessed by light microscopy of histochemically stained sections. The bipolar system operated at a lower power output (13 W) with less heat conduction, and was unaffected by the surrounding medium.

**Key words:** Diathermy, Bipolar, Tissue damage.

## Introduction

Endoscopic bipolar diathermy for electrocoagulation has been used successfully in the treatment of gastrointestinal haemorrhage [4]. The principle advantage of the bipolar diathermy system is patient safety [5]. Bipolar diathermy does not require an indifferent electrode or "diathermy plate" to complete an electrical circuit between the patient and the generator or "diathermy machine". Consequently, bipolar diathermy carries no risk of contact burns and cannot interfere with the function of implanted electronic devices.

In theoretical terms, provided there is good contact between a bipolar current source and the tissue, electrocoagulation should occurr irrespective of the surrounding fluid medium. The area of tissue damage may be expected to be confined to the point of application of a bipolar electrode because the production of thermal energy does not depend upon the conduction of current between an active and indifferent electrode. Monopolar diathermy requires that the whole patient should behave as an electrolyte solution which conducts current between two electrodes. Although the danger of applying monopolar diathermy to structures on pedicles is well known [3], bipolar diathermy has not gained wide acceptance in the surgery of the external genitalia, perhaps because of a lack of experimental evidence to support the theoretical considerations.

At present bipolar diathermy is used in microvascular surgery and in neurosurgery because it is a precise and effective means of coagulation producing little observed tissue damage. However, there is little experimental evidence to substantiate this observation [5, 6]. For these reasons a 6FG bipolar probe designed for use through a gastroscope for upper gastrointestinal haemostasis was tested in experimental animals with a view to its possible urological applications.

## Materials and Methods

Fifteen female New Zealand White Rabbits were used for acute and survival experiments. Anaesthesia was provided by a combination of neuroleptanalgesia with abdominal wall infiltration of lignocaine hydrochloride 1%. Mid-line abdominal incisions were made in all cases.

A standard 2 mm diameter bipolar diathermy probe (A.C.M.I. Stamford NY) equipped with a coaxial irrigating channel was used throughout. A monopolar diathermy probe of exactly similar proportions was used for comparison of effect (Fig. 1). A bipolar diathermy machine (A.C.M.I. "Bicap") with a power output 13–49 watts was linked to both bipolar and monopolar electrodes.

The indifferent monopolar electrode was provided by a lead plate wrapped in a linen sheath soaked in a brine solution, which could be applied to a 10 cm x 10 cm shaved area of skin on the animal's back.

Temperature measurements were recorded on a multichannel recorder linked to wire thermocouples of 0.2 mm tip diameter (RS Components London UK) (Fig. 2). Electronic ice points were used as temperature references.

Core temperature was recorded by a thermocouple implanted in the rectus muscle and all temperature measurements were calculated with reference to any change in core temperature. To establish the coagulating effeciency of the probes the rabbit vesical artery and vein were used. The artery was transected on the lateral surface of the bladder and a 1 mm window was cut in the wall of the vein. The ends of probes were applied accurately to the apertures in the vessels (coaptive coagulation) and a 1 s pulse of current at increasing

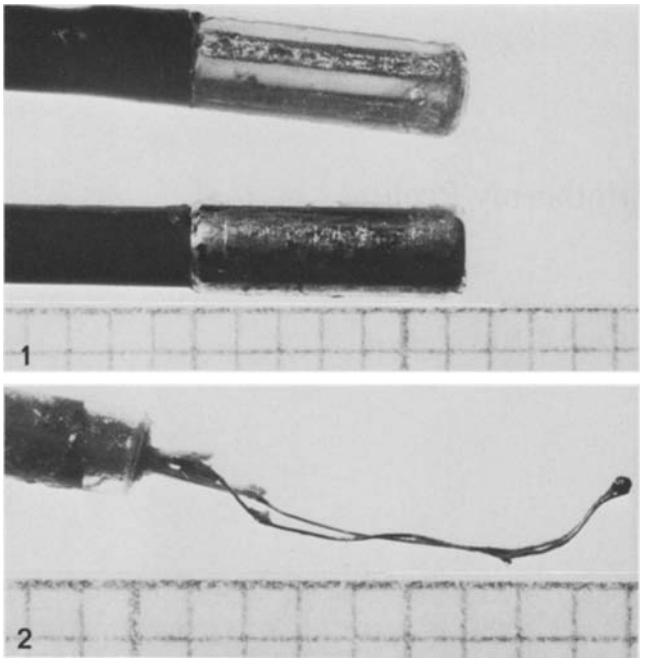

Fig. 1. Bipolar and monopolar diathermy probes. 1 mm scale

Fig. 2. Wire thermocouple

Table 1. Effect of surrounding medium

| | Monopolar | Bipolar |
|---|---|---|
| Air | 35 W | 13 W |
| N. saline | No effect | 13 W |
| Sterile water | 47 W | 13 W |

power settings was applied until the minimum setting which would always produce coagulation was discovered. This procedure was repeated with vessed and probe immersed in normal saline and in sterile water.

To measure heat conduction, 10 rabbits were used. The left fallopian tube was straightened and held along the axis formed by its mesentery. Two thermocouples were introduced into the lumen of the fallopian tube and fixed 10 mm apart with 8/0 sutures.

The diathermy probe was placed directly over the proximal thermocouple and a 1 s pulse of current applied. The thermocouple was then moved 2 mm distant from the first point of application and a second pulse of current applied in the new position. The procedure was repeated until the final measurement was made with the probe directly over the distally placed thermocouple. This method was designed to reveal any alteration in thermal conductivity due to the tissue effects of previous diathermy.

Five rabbits were used for the histochemical assessment of the tissue damage caused by bipolar diathermy. The probe was applied to bladder mucosa through a small vesicotomy which was closed around the probe and the bladder emptied of urine. The diathermy site was marked on the serosal surface with 4 sutures circumscribing the tip of the probe.

Fulguration was achieved by application of a current of 13 watts for 1 s. Vesical and laparotomy incisions were closed and the animals allowed to recover. The bladders were removed 24 h later

Table 2. Temperature rise (°C) at 0.2 and 4mm from the point of application of bipolar and monopolar diathermy to the rabbit fallopian tube

| Animal | Distance of bipolar probe from thermocouple | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 4 | 2 | 0 |
| $R_1$ | 3.1 | 1.0 | 0.5 | 0 | 1.5 | 2.4 |
| $R_2$ | 3.5 | 1.7 | 0 | 0 | 2.1 | 3.2 |
| $R_3$ | 2.9 | 2.0 | 0 | 0 | 2.3 | 3.1 |
| $R_4$ | 2.6 | 2.1 | 0.2 | 0 | 2.2 | 3.2 |
| $R_5$ | 3.1 | 1.2 | 0 | 0 | 1.7 | 3.0 |
| Average temp rise | 3.04 | 1.6 | 0.14 | 0 | 2.16 | 2.98 |
| Animal | Distance of monopolar probe from thermocouple | | | | | |
| | 0 | 2 | 4 | 4 | 2 | 0 |
| $R_6$ | 19.8 | 9.0 | 1.4 | 3.0 | 12.5 | 20.2 |
| $R_7$ | 20.0 | 8.0 | 2.0 | 3.5 | 9.5 | 19.5 |
| $R_8$ | 21.0 | 9.5 | 3.0 | 2.7 | 8.0 | 18.0 |
| $R_9$ | 19.0 | 8.2 | 2.6 | 2.3 | 8.7 | 19.0 |
| $R_{10}$ | 22.0 | 9.3 | 3.4 | 3.6 | 9.8 | 21.0 |
| Average temp rise | 20.36 | 8.60 | 2.48 | 3.02 | 9.70 | 19.54 |

and a 4 mm x 4 mm section of bladder wall around the site of fulgaration, was snap frozen in liquid nitrogen. 5 μm sections were cut from unfixed tissue.

Mitochondrial NADPH diaphorase activity was demonstrated with a co-enzyme B technique and visualised with nitro blue tetrazolium.

## Results

The power requirements for effective electrocoagulation in air, normal saline and sterile water are summarised in Table 1. The bipolar machine was consistently effective at a power output of 13 watts. The monopolar system was ineffective in normal saline and required the maximum power output of this generator for electrocoagulation under water.

The tissue heating effects of each diathermy probe are recorded in Table 2 and are summarised in Fig. 3. Photomicrographs of sections of normal rabbit bladder mucosa subjected to 1 s bipolar diathermy at 13 W are shown in Figs. 4 and 5. The staining technique for diaphorase (Fig. 5) shows full thickness muscle damage which does not spread beyond the site of application of the probe.

## Discussion

These experiments confirm the observations of those who have used bipolar diathermy to coagulate bleeding gastric ulcers. Jensen [2] reported that bipolar diathermy stopped

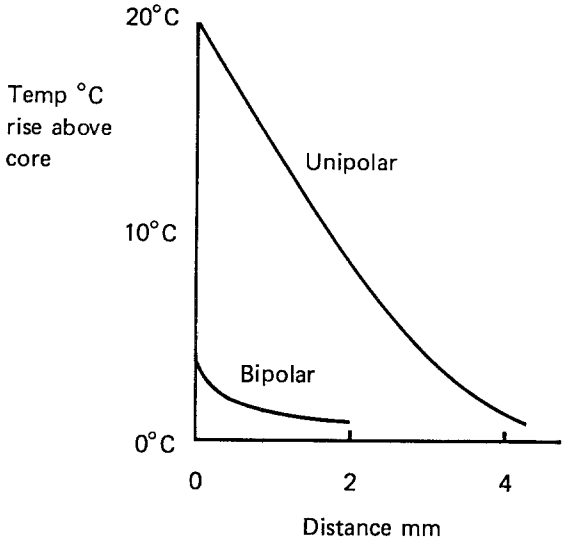


Fig. 3. Conduction of heat from point of diathermy

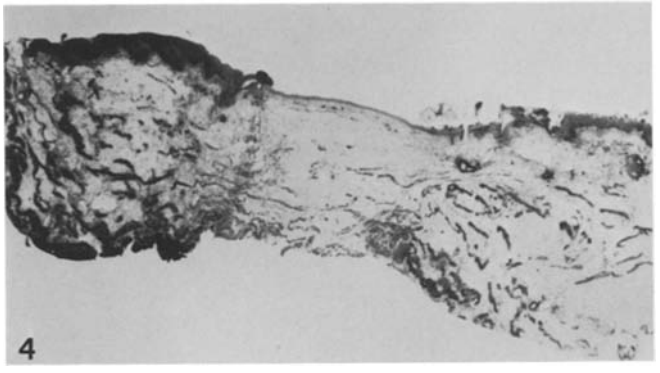


Fig. 4. Diathermy damage to rabbit bladder mucosa (H & E stain)

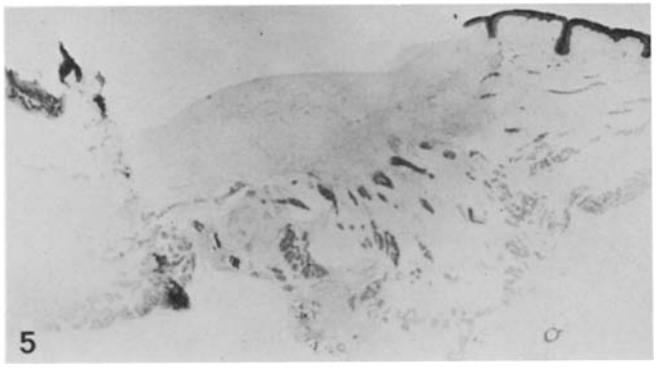


Fig. 5. Precisely demarcated, 2 mm zone of tissue necrosis caused by bipolar diathermy, shown by diaphorase staining technique

the bleeding in 20 out of 30 gastric ulcers. Full thickness injury to the gastric wall occurred in 17% of these cases compared with 53% of the same number treated successfully by monopolar coagulation. In a review of the treatment ob bleeding gastric ulcers in 663 patients Veerhoeven et al. [6] report that histological evidence of external muscle injury occurred in 30% of those treated by bipolar diathermy as opposed to 60% of those treated by the monopolar modality. In these experiments bipolar diathermy was an effective means of coaptive electrocoagulation at one third the power output of the equivalent monopolar device. The efficacy of coagulation at 13 W was not altered by the surrounding fluid medium which has particular implications for percutaneous renal surgery in which effective coagulation using isotonic irrigating solutions would be of advantage.

At the lowest power setting of the "Bicap" bipolar generator bladder mucosal fulguration caused muscle damage in all cases. However, there was no lateral spread of tissue necrosis and this suggests that even lower power fulguration may provide a precise means of destroying superficial bladder mucosal lesions without unwanted tissue necrosis.

The experiments in heat conduction suggest that bipolar diathermy causes less tissue damage than its monopolar counterpart. Irreversible tissue damage due to protein denaturation occurrs at 55–60 °C [1]. An average temperature rise of 19.9 °C above an average core temperature of 35.9 °C was recorded in the lumen adjacent to the monopolar diathermy probe. Due to electronic interference between the diathermy source and the recorder, there is a 1 s delay between application of current and temperature recording: it is therefore probable that the monopolar diathermy was causing sufficient heat conduction to denature protein. The bipolar system compares favourably producing a maximum temperature rise of only 3.5 °C under similar circumstances.

Reduction of heat conduction may be of advantage in surgery of the external genitalia. When monopolar diathermy is applied to a pedicled structure tissue heating occurrs proximal to the point of application. Blood vessels within the pedicle provide the principle channel for conduction of electricity and heat between active and indifferent electrodes causing definite risk of thrombosis. The absence of the indifferent electrode and of transmitted tissue heating may well remove this risk.

## Conclusion

This experimental work suggests that bipolar diathermy has advantages over the monopolar system for electrocoagulation and for tissue fulguration. Bipolar diathermy is effective under normal saline and water. The benefit to patient safety is well recognised.

Advances in technology may provide a bipolar electrode suitable for tissue cutting, but in the meantime the clinical applications of bipolar diathermy in urological surgery should be explored.

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